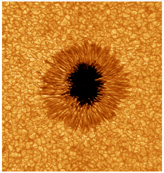
Two-fluid simulations of solar partially ionized atmosphere

May 9, 2016

Sun atmosphere layers

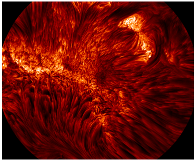
Photosphere

- collisions dominated: LTE, MHD
- relatively easy observations
- diagnostics techniques well developed



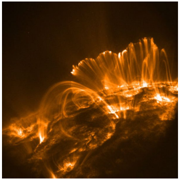
Chromosphere

- not fully collisionally coupled: NLTE, No MHD (frequently not taken into account)
- very few spectral lines
- complicated radiative diagostics



Corona

- magnetically dominated
- very low density
- all ionized, MHD can be applied



Plasma models

- system of first order non linear partial differential equations which must be integrated in time
- Approximations:
  - MHD-1fluid: all the particles are considered as a whole. Assumption: strongly collisional plasma. A system of 8 unknown variables $(p, \rho, v_x, v_y, v_z, B_x, B_y, B_z)$
  - 2-fluid: Neutral particles do not feel electromagnetic forces and may move differently from charged particles so collision rates between charged particles and neutral particles may not be the same like inside one specie. We consider the fluid variables (p, ρ, v_x, v_y, v_z) different for charged and neutral particles. A system of 13 unknown variables.
  - furthermore we could split the charges into ions and electrons as sometimes forces act differently on them or even consider each specie of ions in order to gain more resolution over the process

Partially ionized plasma

While 1fluid is a good approximation for photosphere (all neutral) or corona (all ionized) it might not be so precise for the chromosphere and transition region where plasma is partially ionized and we try to apply the 2 fluid approximation

- integrate numerically the 13 equations in order to get time evolution
- initial conditions based on observations

By having more knowledge of the evolution of different kind of particles we hope to understand better things that are not very clear yet like the wave propagation in the sun atmosphere or the heating in its upper part.

Simulation

- generation of initial conditions (python)
- executing fortran 90 parallel code which solves the PDE system and outputs the results in hdf5 files
- visualization and analysis (visit or python)

Test result in visit

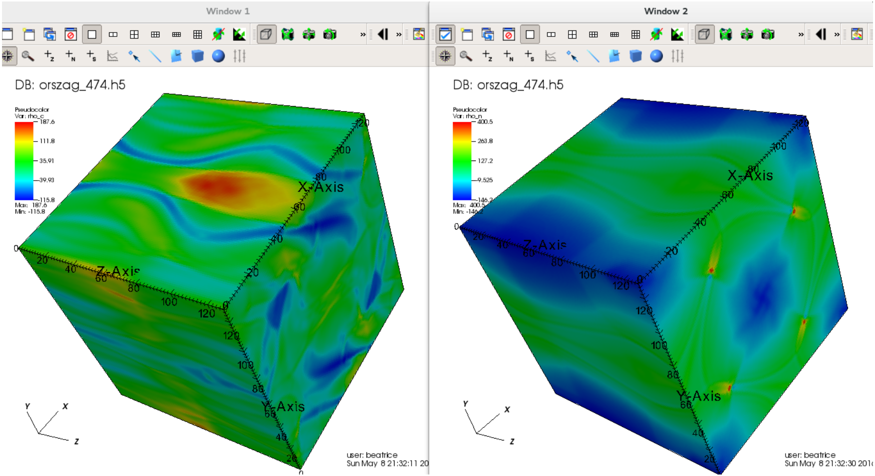


Figure 1: density of charges and neutrals in Orszag test after 474 iterations where they evolve independently (collision terms between neutrals and charges are set to 0)